# Tips

- Go through all the materials. Make ‘long’ notes. Then, make a second neater set of your own notes
- Go through all tutorial sheet questions, then sample paper
- Some questions will seem easier than other. Make sure you get the more straightforward marks first
- When revising, you can do the same question more than once. It’s not necessarily enough to know something, you should also aim to be able to do it quickly, so time yourself and try to reduce the amount of time needed at each attempt
- Show as much working as you reasonably can
- Write legibly
- If you have spare time, keep checking your answers and re-read the questions. I guarantee there will still be an error to find somewhere – so find it!

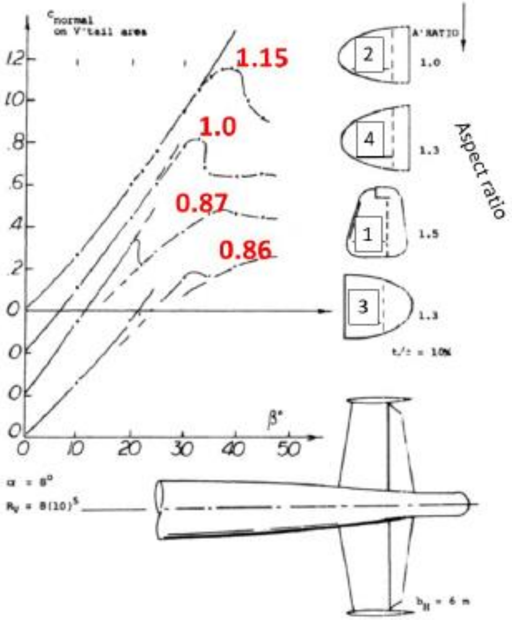
**Q6** A vehicle has a drag coefficient of 0.3 based on a reference area of [a]$m^2$. Driving at sea level where air density is $1.225 kgm^{-3}$ at a speed of [v]$ms^{-1}$, the drag coefficient increases by 5% if the windows are opened. What is the increase in drag in N if the windows are opened?

*[3 marks]*

$$\Delta D = 0.05 \times 0.3 \times 1.225 \times v^2 \times a \times 0.5$$

**Q7** The figure below shows the normal force coefficient on a twin vertical fin configuration against aircraft yaw angle, defined using the total normal force on both fins and the total area of both fins as the reference area. The maximum normal force coefficient has been labelled for each curve (note that a displaced axis has been used, so curves are offset as plotted). At a speed of 40m/s, with reference area=1.5m2, air density=1.2kg/m3, the maximum total normal force on configuration 1 is [1253] N. If a configuration were to be selected to provide the greatest directional stability of the aircraft, the best option would be [1] because it has [greatest coefficient gradient around zero yaw].

*[9 marks]*




1 - this is actually the fin arrangement of the Do 17 aircraft. A primary goal of the fins is directional stability, which means that for any change in yaw angle, the change in lateral force should be a large as feasible to generate a restoring moment in yaw. In turn, this implies the fin with the largest rate of change of lateral force with respect to angle is preferable.

1253, calculation is $0.87 \times 0.5 \times 1.2 \times 40^2 \times 1.5 = 1253N$. Note that this is the total force on both fins, and the area is the area of both (as defined in question).

What if that was moment coefficient about CG?


$$C_m = 0.87 \times 0.5 \times 1.2 \times 40^2 \times 1.5 \times \frac{x}{l_{ref}}$$

…just multiply by the nondimensional moment arm

What if some of the fin (ratio f) was missing (on the assumption Clmax unchanged)?

$$C_m = 0.87 \times 0.5 \times 1.2 \times 40^2 \times 1.5 \times (1-f) \times \frac{x}{l_{ref}}$$

What if it was gradient of moment?

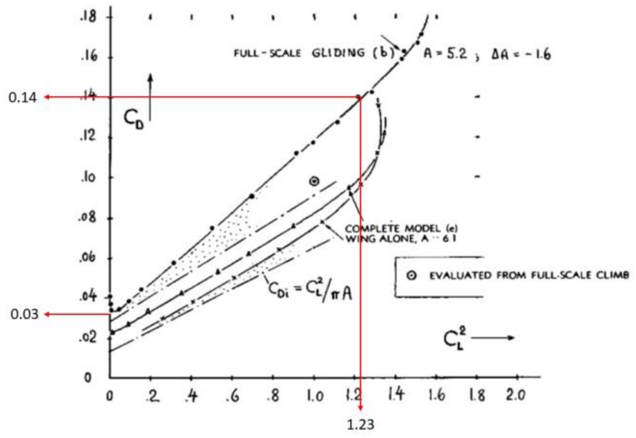
$$C_m = \frac{dC_{Lfin}}{d\beta} \times 0.5 \times 1.2 \times 40^2 \times 1.5 \times \frac{x}{l_{ref}}$$

…could be estimated from previous graph, looks to be about 1.8/rad

Lots of ways to use coefficients but they are all essentially the same – which is of course why we like them!

**Q8** The figure below shows the drag polar (plotting $C_d$ (aircraft drag coefficient) against $C_l^2$ (square of aircraft lift coefficient)) for a propeller driven fighter aircraft. In this figure, using the curve labelled 'full-scale gliding', calculate the glide speed in m/s that corresponds to the highest value of $\frac{L}{D}$, if air density is $1.225kgm^{-3}$, wing area is [a]$m^2$ and aircraft mass is [w]kg, with g=$9.81ms^{-2}$.

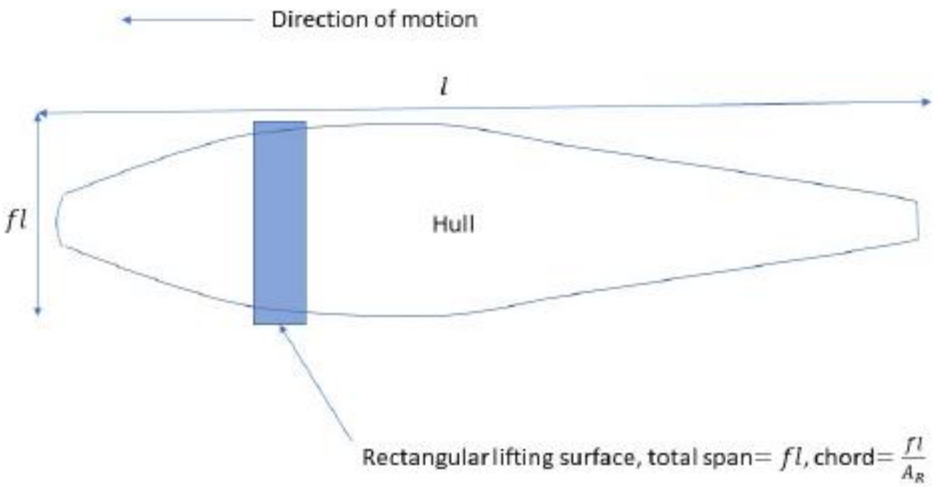
*[10 marks]*




First we need the gradient of $C_d$ with respect to $C_l^2$, which from the figure is $\frac{0.11}{1.23} = 0.08943$. The best L/D $C_l$ is then $\sqrt{\frac{0.03}{0.08943}} = 0.5792$. The speed for this lift coefficient is then $v = \sqrt{\frac{w \times 9.81}{0.5792 \times 0.5 \times 1.225 \times a}}$.

**Q9** Assume that the lifting surface here can achieve a maximum lift coefficient of 3 before stalling, and that there is a single rectangular lifting surface with an aspect ratio of [a]. If a hydrofoil ship is built from a single lifting surface and limited to a maximum speed of $25ms^{-2}$, with the span of the hydrofoil's lifting surface limited to [f] times the dimensional reference length (in order to permit docking), where the reference length is hull length l, what is the maximum possible mass of the hydrofoil in kg such that it can just leave the water with the lifting surface operating at Clmax travelling at $25ms^{-1}$? The density of the water may be taken as $1000kgm^{-3}$ and acceleration due to gravity as $9.81ms^{-2}$. Based on a dimensional argument you may also assume for this case $\rho l^3 g = mg$ , such that when stationary the hydrofoil ship can float under buoyancy alone.

*[10 marks]*



$$\rho l^3 g = \frac{C_{l_{max}} \frac{1}{2} \rho V^2 f^2 l^2}{A_R} \tag{1}$$

which leads to an expression for

$$l = \frac{C_{l_{max}} \frac{1}{2} V^2 f^2}{g A_R} \tag{2}$$

$$\rho l^3 = \left( \frac{C_{l_{max}} \frac{1}{2} V^2 f^2}{g A_R} \right)^3 \rho \tag{3}$$

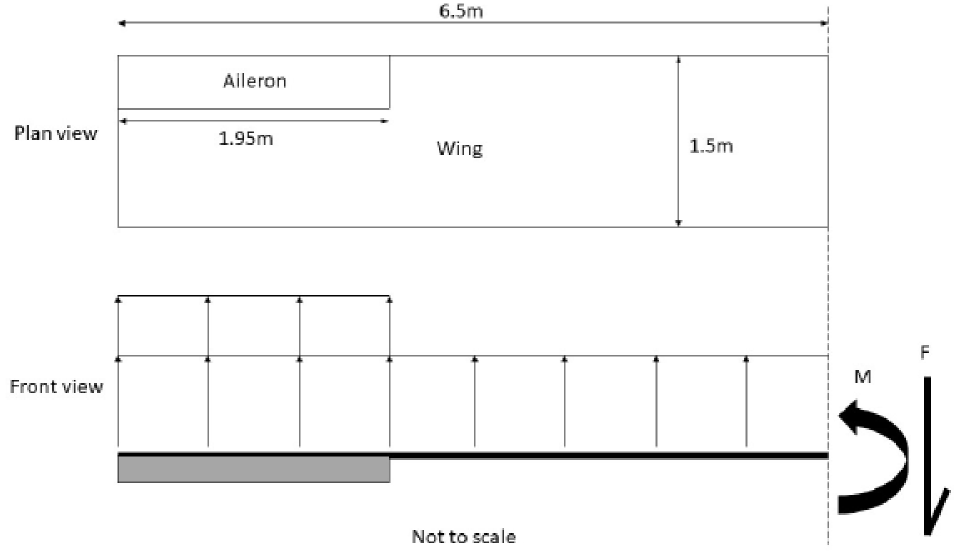
NB - non-examinable comment - this gives rather low masses, of a few tonnes, although the estimate logic is sensible. It would be more accurate to say $\rho f^2 l^2 l g = mg$, ie. the volume is the square cross section times hull length which gives estimates of a few hundred tonnes as

$$\rho l^3 = \left( \frac{C_{l_{max}} \frac{1}{2} V^2}{g A_R} \right)^3 \rho \tag{4}$$

The implication of this is that larger hydrofoils would require lifting surfaces wider than their hull width, necessitating folding for docking, or lower (inefficient) aspect ratios.

**Q12** The figure below shows a sketch of the planform and vertical load distribution on a wing with an aileron deflected, where it is assumed that the load on the wing and along the section of the wing with the aileron is uniform (but the value for each region is different, as indicated in the figure). The overall wing lift coefficient is [cw] without the aileron deflected, and then deflection of the aileron increases the sectional lift coefficient along the span of the wing where the aileron exists by an increment [dc], while the local lift coefficient elsewhere remains unchanged. Air density is $1.225 kgm^{-3}$ and airspeed is [v]m/s. Calculate the wing root bending moment with the aileron deflected as shown in the figure (ie. M, where M is a positive number) in Nm.

*[10 marks]*




$$M = 0.5 \times 1.225 \times v^2 \times (cw \times 6.5 \times 1.5 \times 3.25 + dc \times 1.95 \times 1.5 \times 5.525) \tag{9}$$